

Development of a Detection and Early Warning System for Malaria Risk in the Amazon

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The Peruvian Amazon

- Almost 90% of malaria in the Western Hemisphere is located in the Amazon
- 25% of the malaria burden in the Americas is in 12 municipalities of Peru, Brazil and Venezuela
- 60% of cases in Peru are in the Department of Loreto



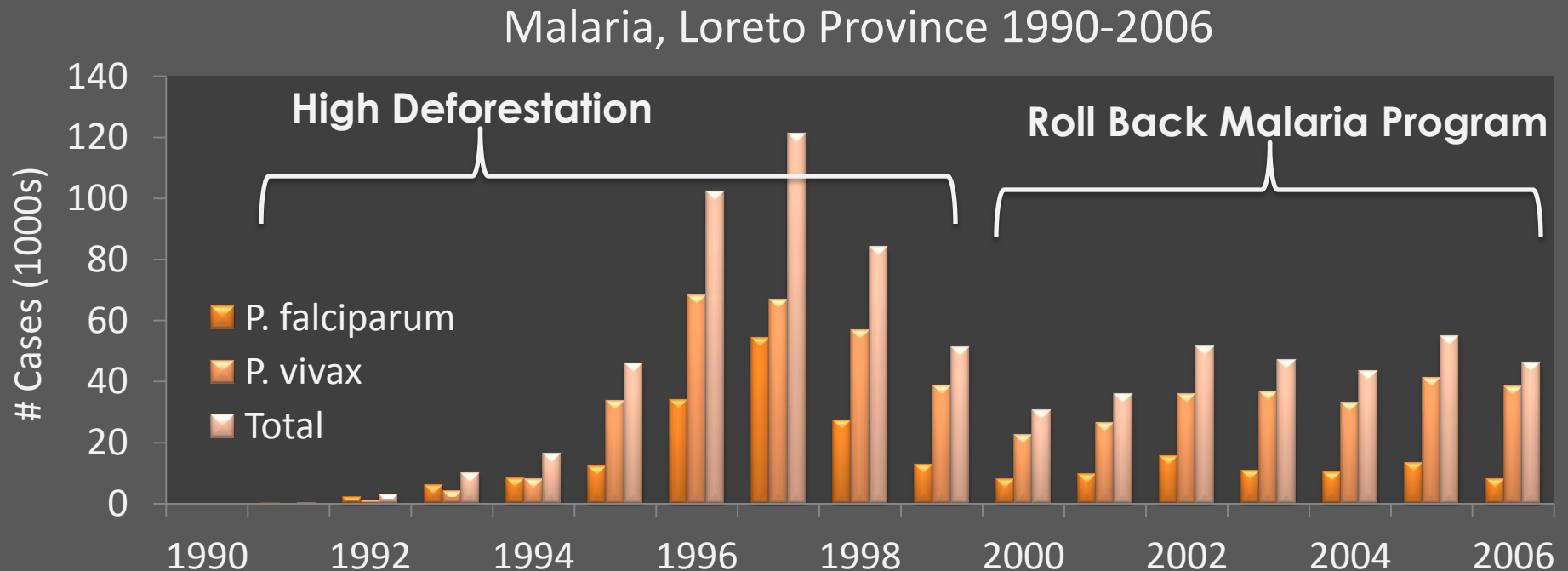
Aims

Feasibility Study: develop a spatially explicit model of malaria transmission risk on the basis of predicted *Anopheles* density and mapped human settlement and activity patterns

End application: operational risk monitoring system to inform decisions on resource distribution and vector management by our collaborators (PRISMA, State Health Ministry, US NMRCDC)

Malaria on the Amazon Frontier

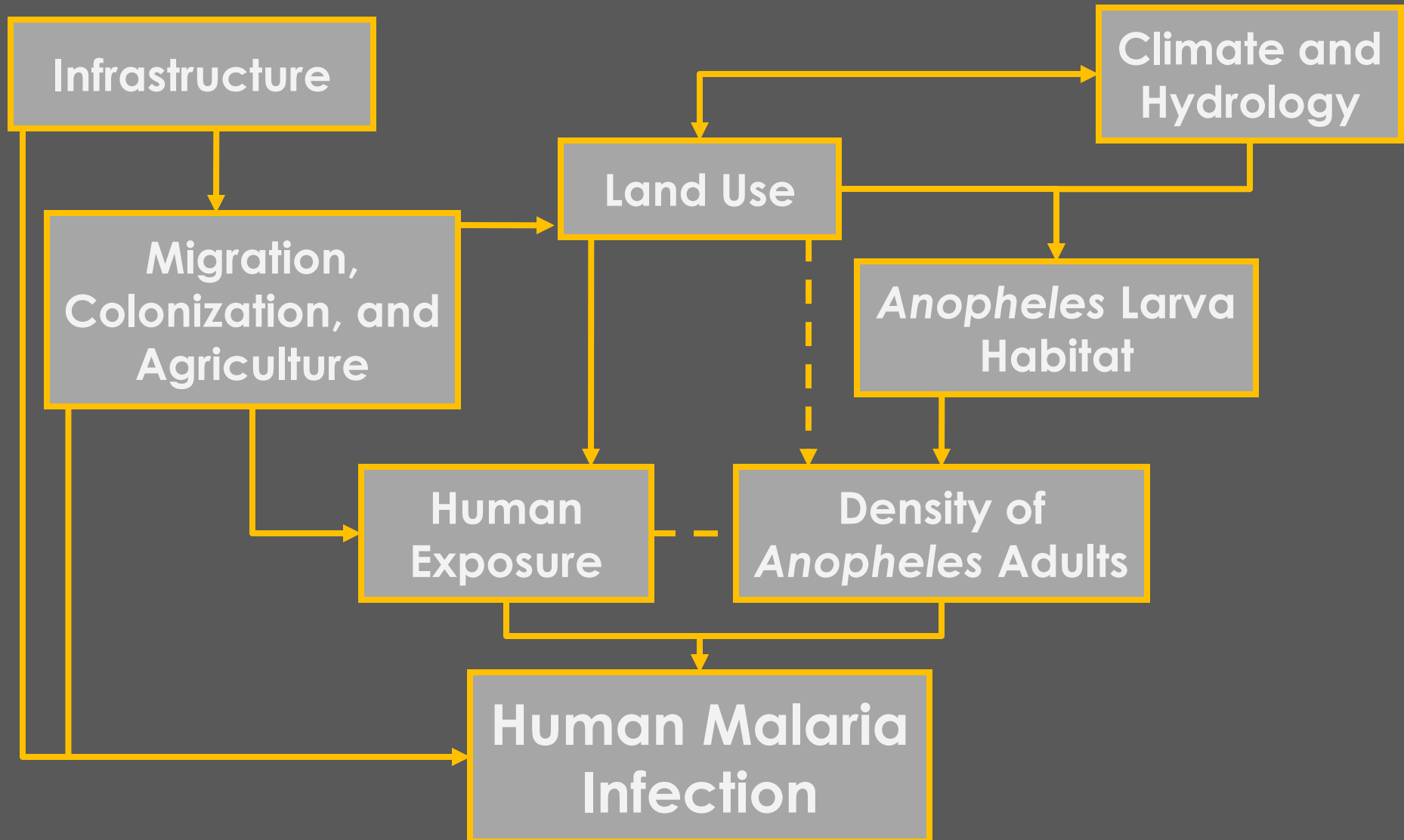
- Relationships between land use, mosquito ecology, climate, human activity, and malaria risk are complex



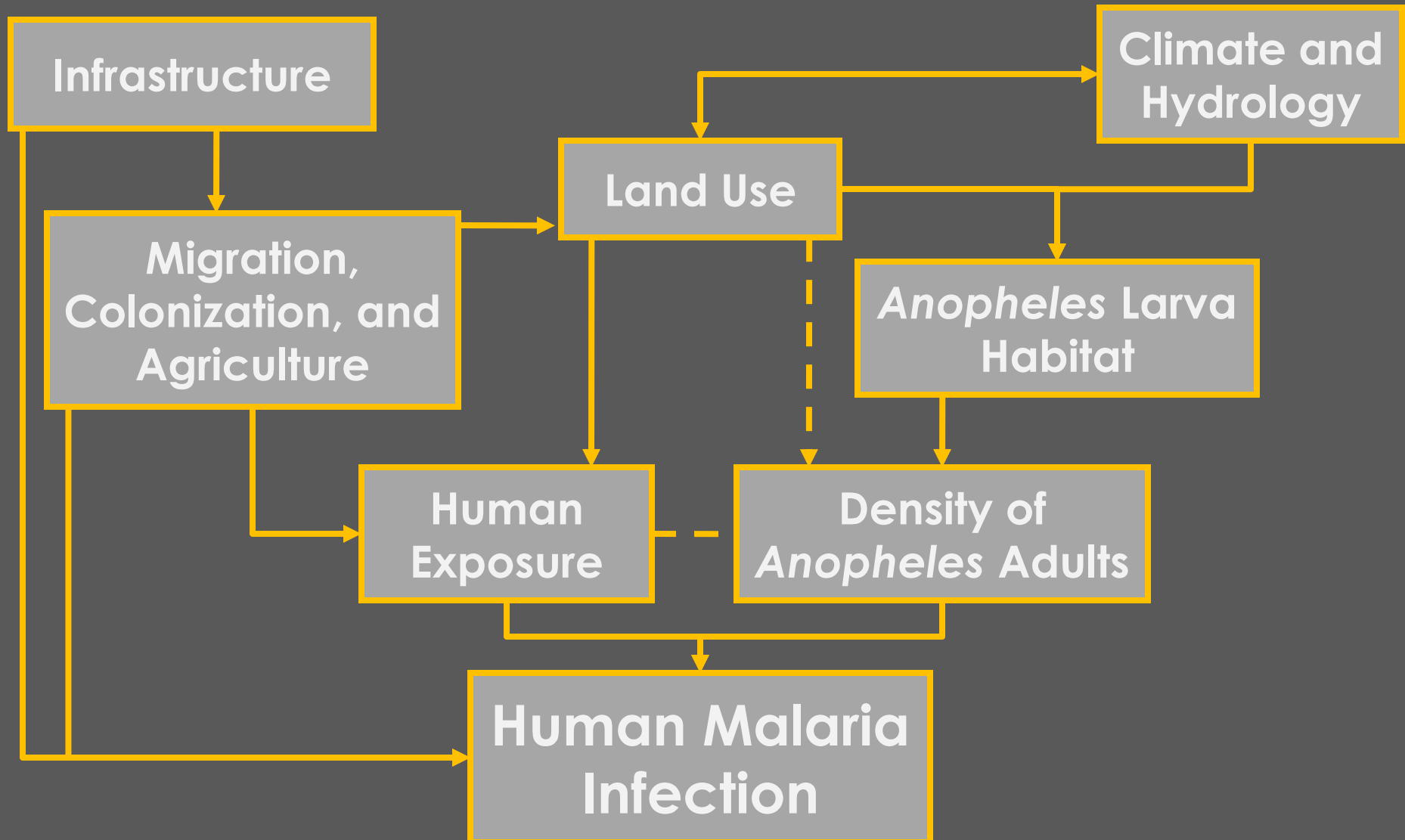
Malaria on the Amazon Frontier

- Relationships between land use, mosquito ecology, climate, human activity, and malaria risk are complex
- But strong biophysical links exist, and they can be monitored and addressed through integrated analysis

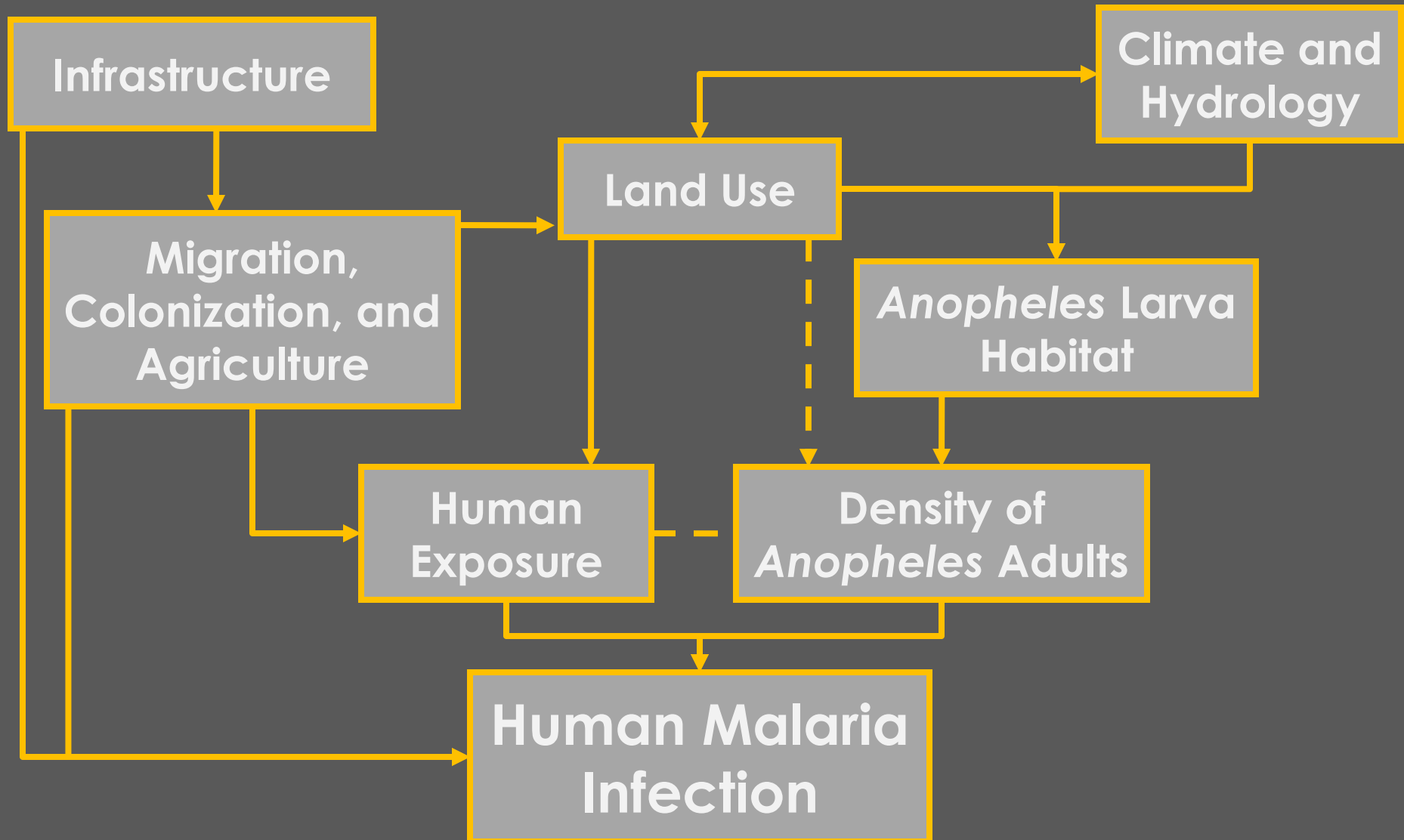
Malaria on the Amazon Frontier



Malaria on the Amazon Frontier



Malaria on the Amazon Frontier



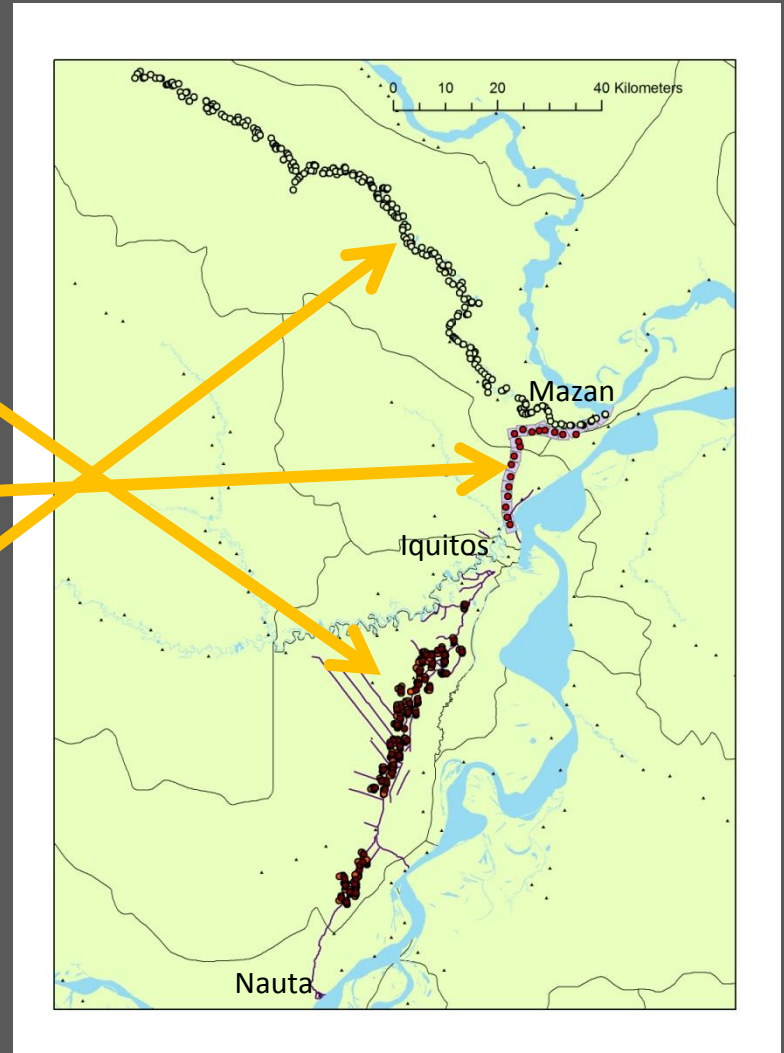
Approach

- Spatio-temporal Ecological *Anopheles* model
 - Input 1: Satellite-based land cover maps
 - Input 2: Meteorological data
 - Input 3: Land Data Assimilation System
- Human Activities and Settlements Map
 - Input 1: Satellite and *in situ* mapping
 - Input 2: Census and Economic data
- Eco-epidemiological Malaria Transmission Model
 - Application: Risk monitoring and prediction

Anopheles Collections

Mosquito Collection

- Iquitos-Nauta road: 1999-2001
- Iquitos-Mazan road: 2007-2011
- Additional survey of logging camps



Land Cover Change

Infrastructure Expansion

- Oil Exploration
- Highway construction
- Urban growth



Land Cover Change

Infrastructure Expansion

- Oil Exploration
- Highway construction
- Urban growth



Migration, Colonization, and Phases of Agriculture Development

Annual Crops



Perennial Crops

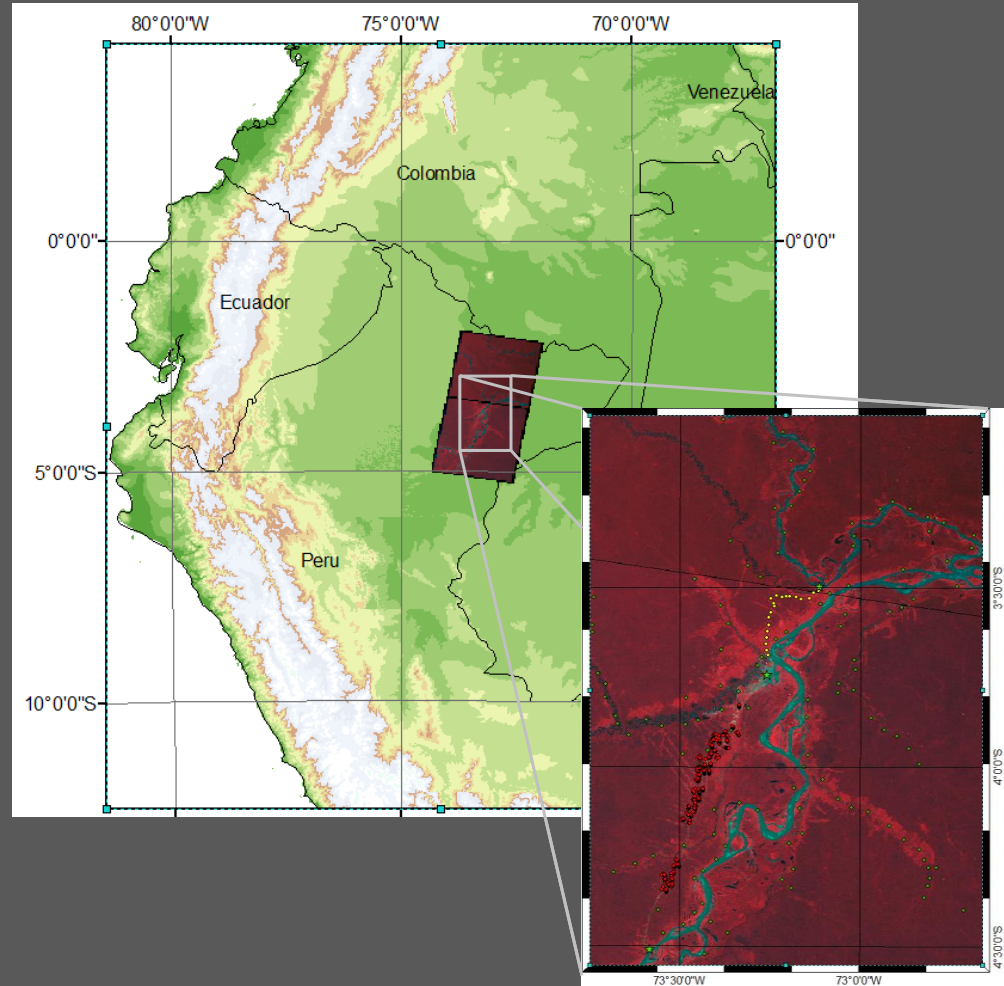


Pastures



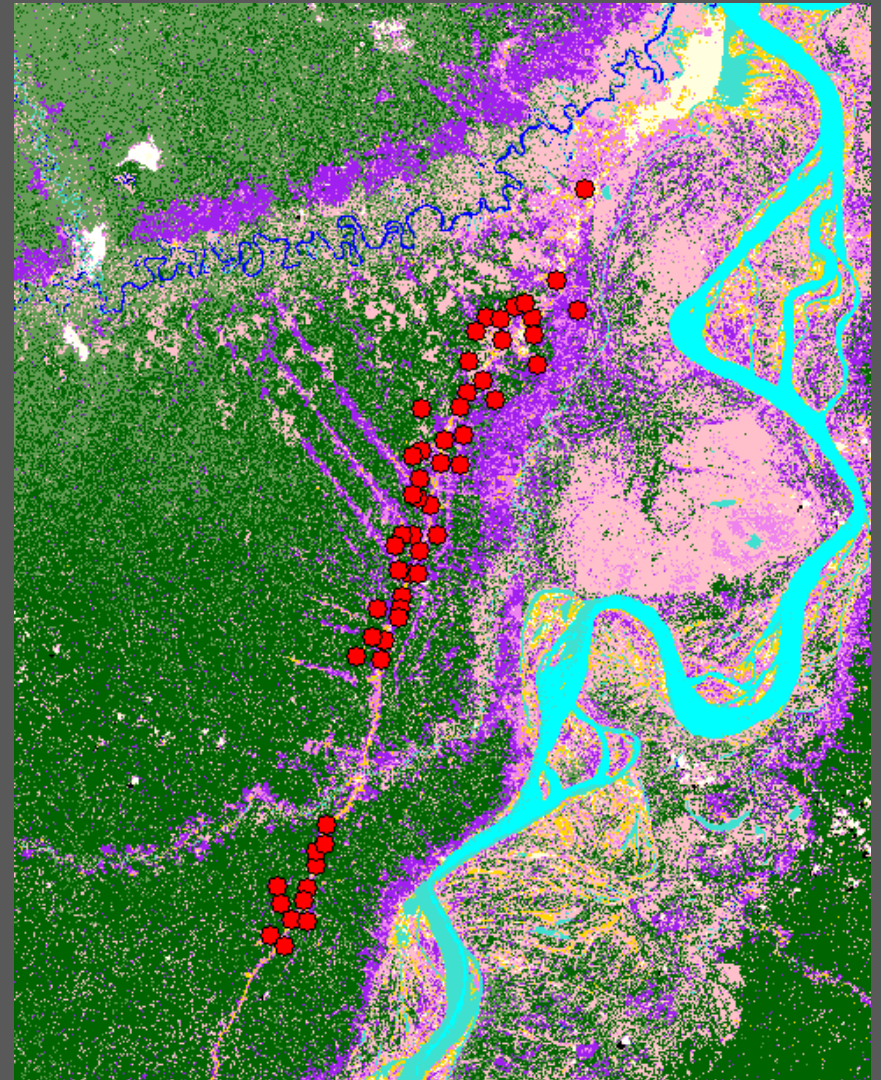
Land Cover Change

- Deforestation and forest disturbance in Peru can be subtle
- Primary tool: Landsat, multi-temporal analysis
- Supplemented with commercial high resolution imagery
- Extensive ground truth



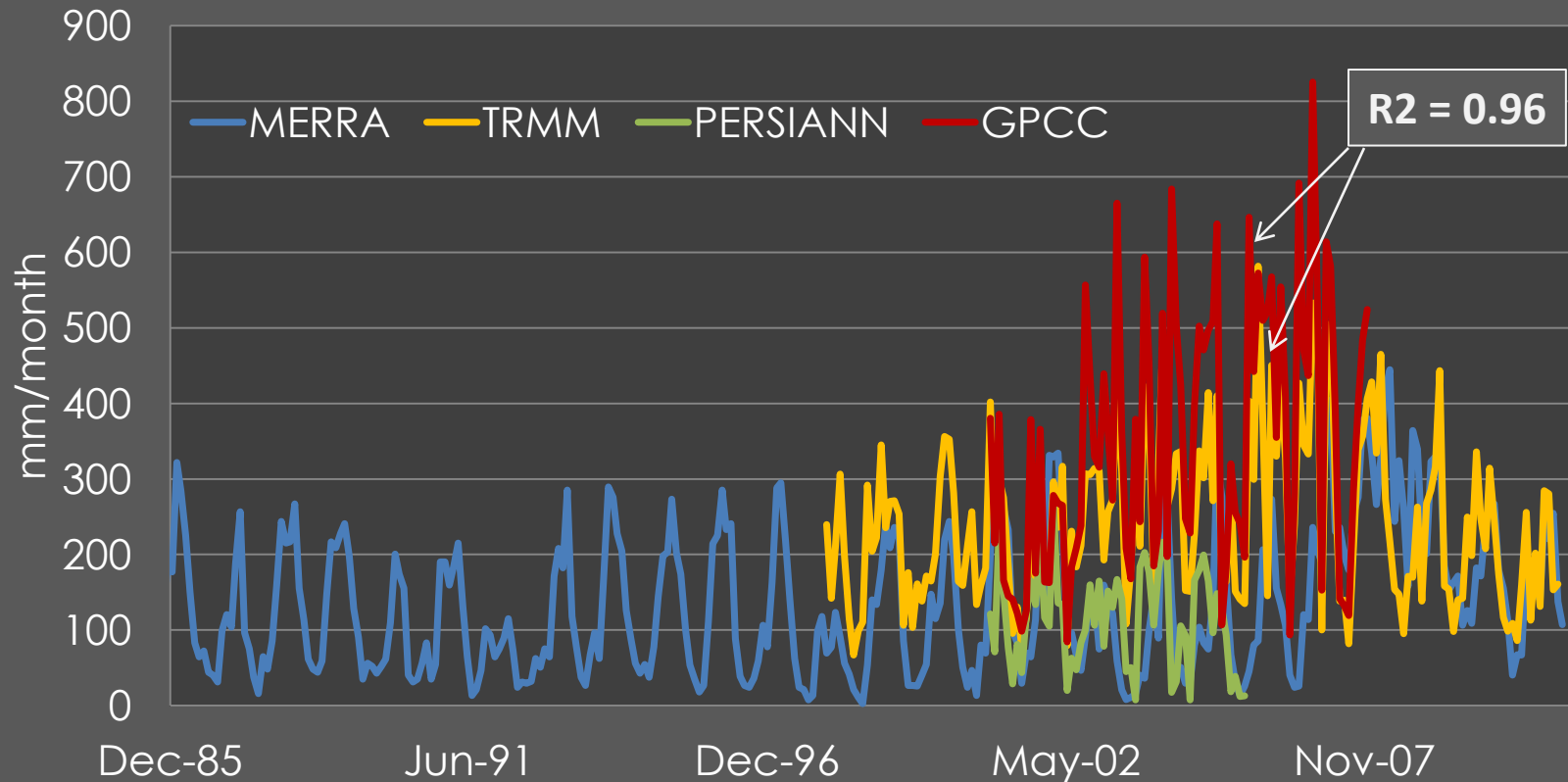
Land Cover Change

- 12 class supervised classification
- Nauta-Iquitos road in 2001 and Iquitos-Mazan road in 2009
- Distinction between forest and non-forest appears to be adequate
- Identification of secondary forest is not



Meteorological Data

Precipitation



Land Data Assimilation System

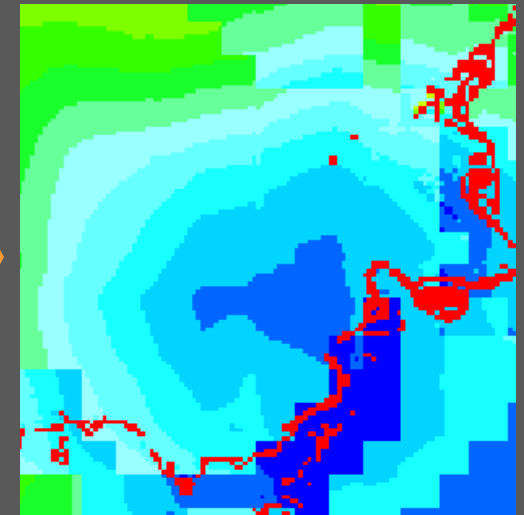
Landscape Information



Update Observations

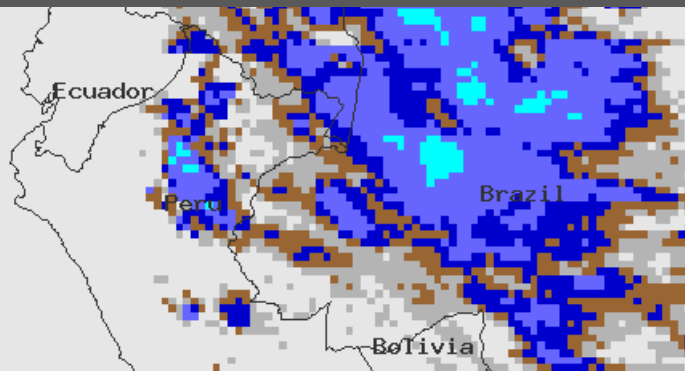


LDAS Output

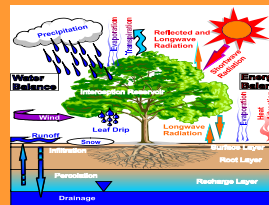


- Hydrological fluxes and storage
- Localized meteorology
- Surface energy balance

Meteorological Data

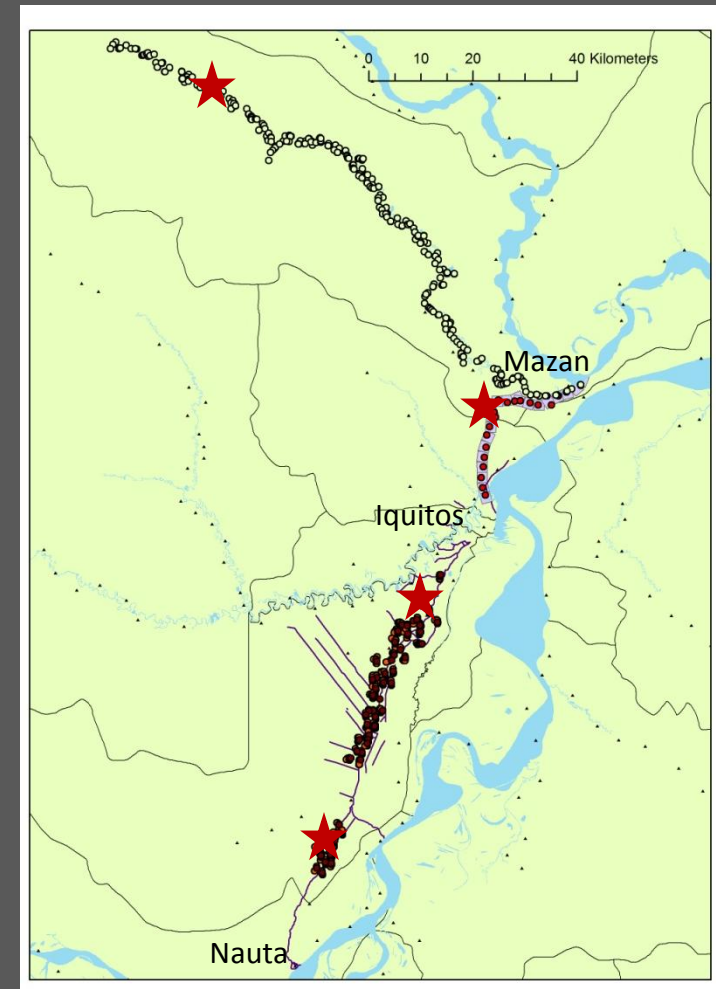
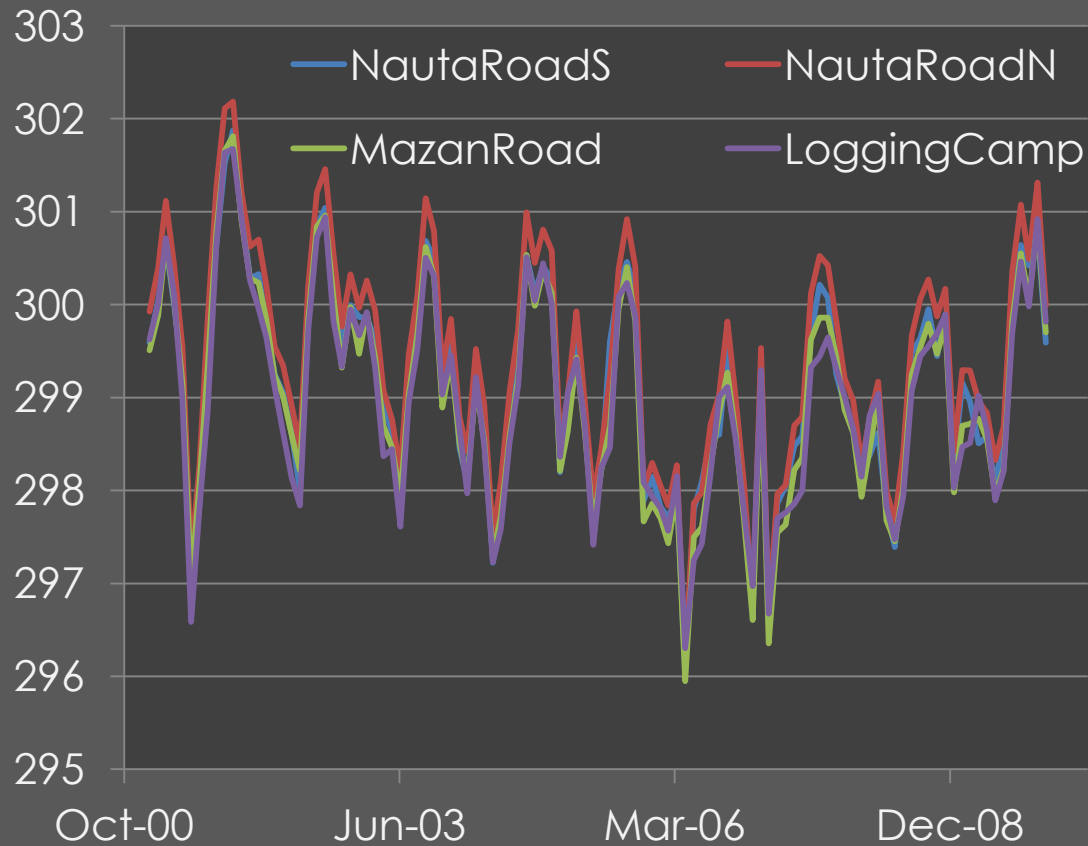


Numerical Model



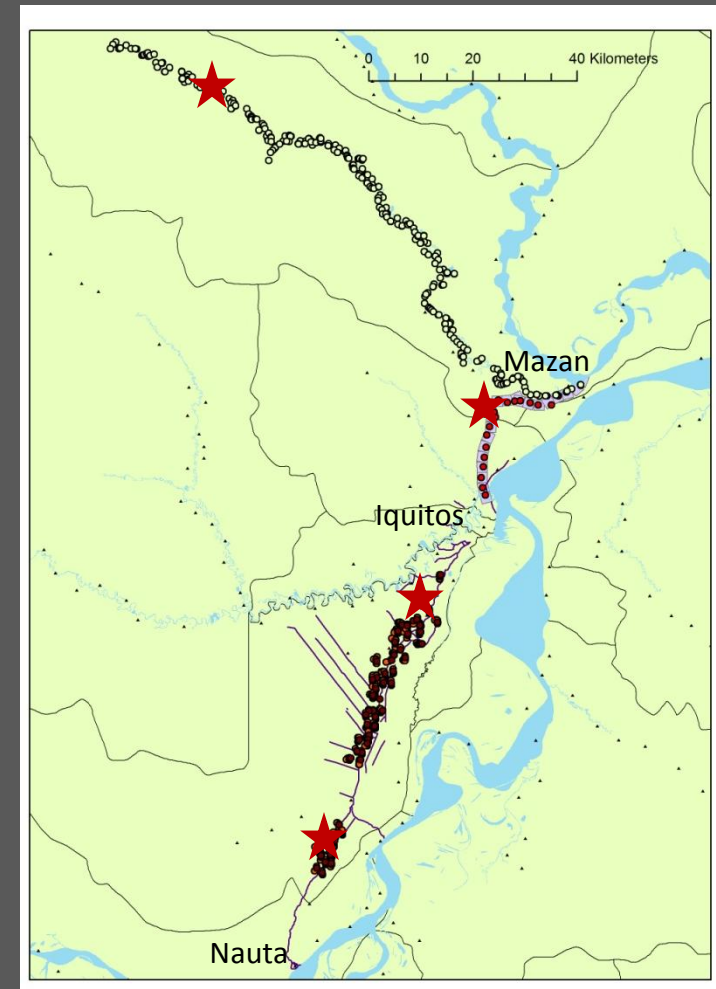
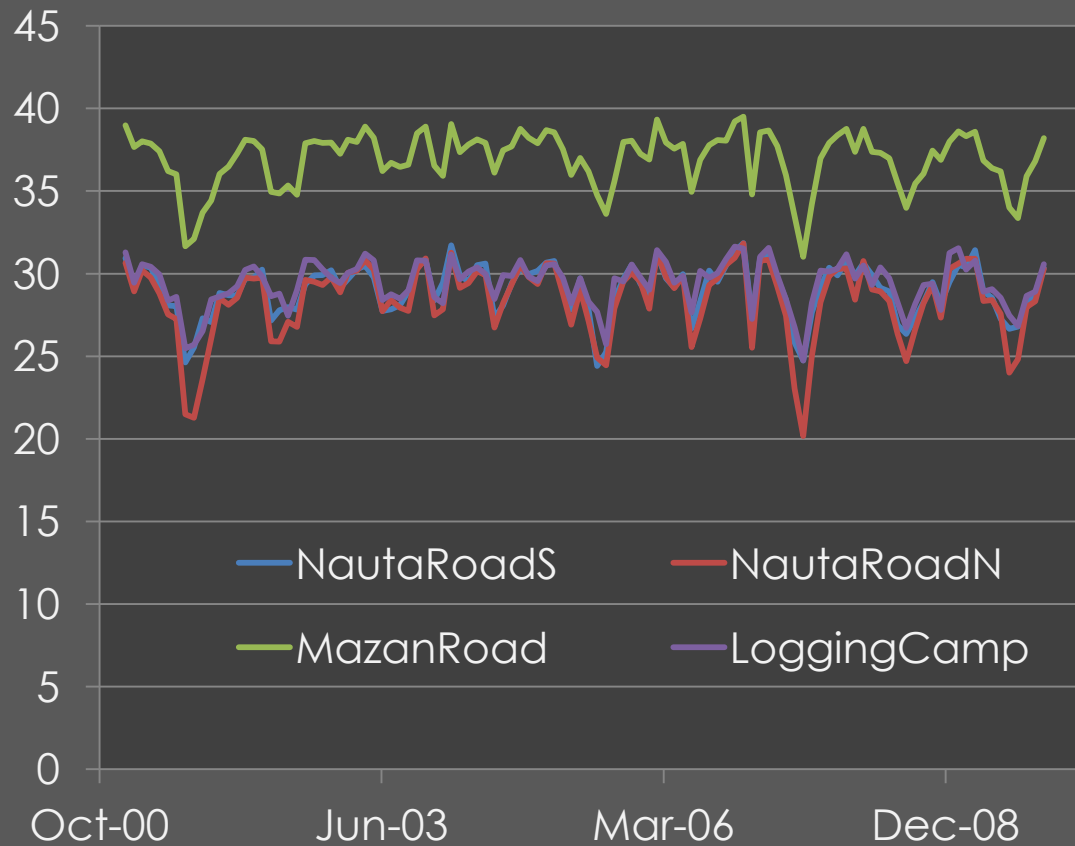
Land Data Assimilation System

Soil Surface Temperature



Land Data Assimilation System

% Soil Water Content, top 10cm



Spatially Explicit *Anopheles* Model

DATA

Adult anopheles data (13 species):

- 1) 56 sites along the Iquitos-Nauta Rd sampled every 3 weeks from Sept. 2000 to Aug. 2001
- 2) 20 sites along the Iquitos-Mazan Rd sampled once every 3 weeks from Feb. 2009 to Aug. 2010
- 3) Mazan & Napo Rivers, logging basecamps and communities: April 2007, August 2007, August 2008, February 2009, August 2010
- 4) Twice-monthly surveillance in Mazan city from September 2007 to December 2009

Anopheles larva data (17 species) in 56 sites along the Iquitos-Nauta Rd sampled once every 3 weeks from 9/2000-8/2001

Independent Spatio-temporal Malaria Ecology Models

- Identifies proper scales of analysis
- Landscape ecology measures (FRAGSTATS)
- Define (PAF LDAS) environmental determinants for:

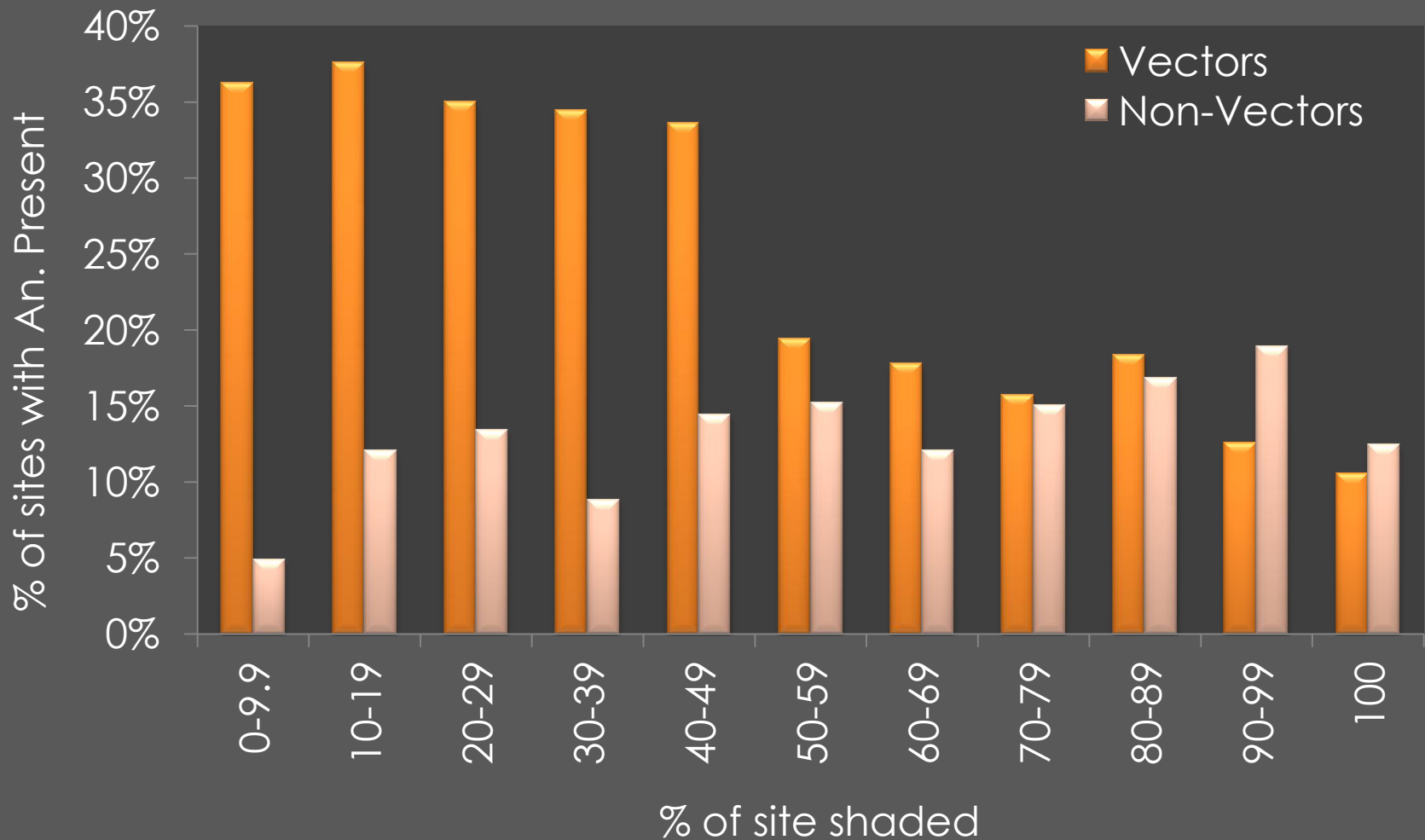
Adult Anopheles

Anopheles Larva

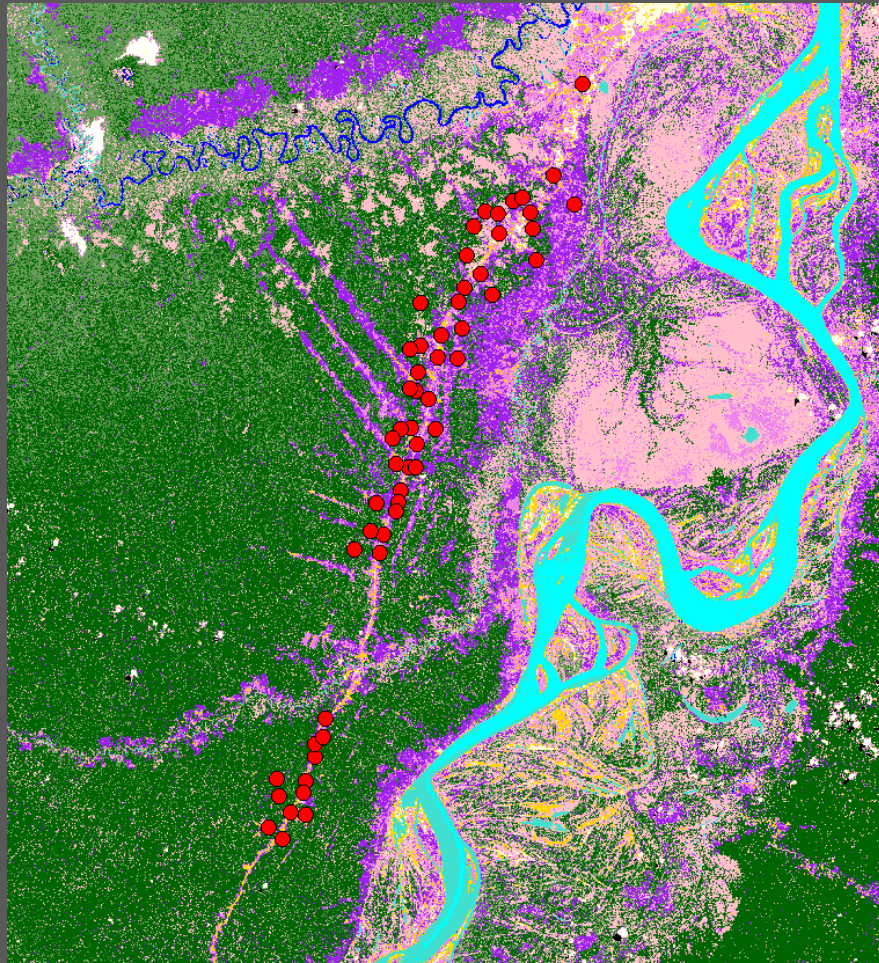
Joint Spatio-temporal Models of Adult and Larval *Anopheline* Ecology

Predicted *An.* density across the region

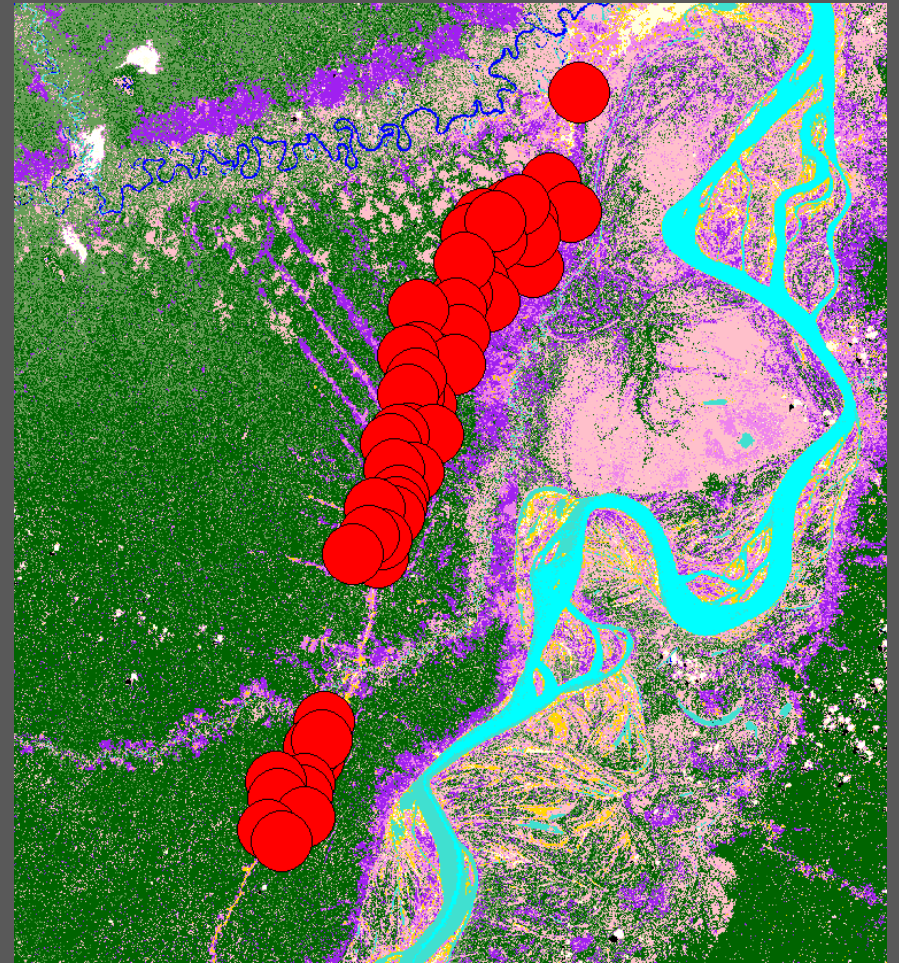
Spatially Explicit *Anopheles* Model



Spatially Explicit *Anopheles* Model



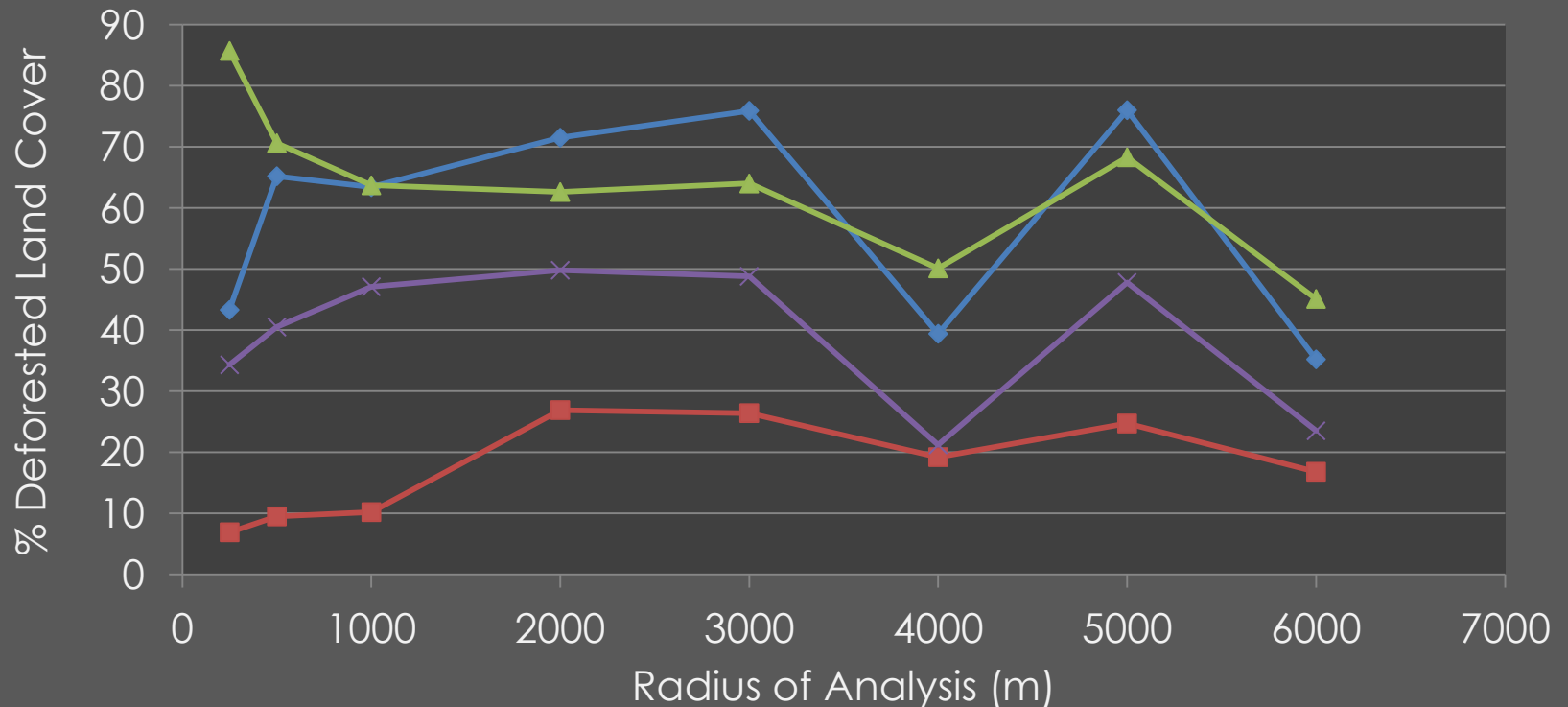
250 m radius



1000 m radius

Spatially Explicit *Anopheles* Model

Deforestation vs. Scale



State of Analysis

- Land Surface Model simulations show strong potential to inform predictions of *Anopheles* distribution
 - Active data assimilation not yet tested
- The relationship between land cover and mosquito distribution is robust and species-specific, and it appears to be strongest at 3-5km radius of influence

Next Steps

- Integrate LDAS results to *Anopheles* distribution models
- Compile Human Settlements and Activities map
- Implement spatially explicit transmission risk model
- Continued and enhanced mosquito collection and malaria monitoring
- Work with end-user partners to ensure that the products are taking on a useful form

THANK YOU